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ONTARIO

DEPARTMENT OF EDUCATION

PHYSICS

Senior Division

Grade 13

Replacing the Grade 13 Physics course as printed in Curriculum S.20, Physics, Senior Division

For Introduction in September, 1965

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PHYSICS

Grade 13

GENERAL COMMENTS

This course is designed to present Physics to Grade 13 students, not as the study of a mere body of facts, but as a continuing process by which men seek to understand the nature of the physical world.

All topics listed should be treated quantitatively and in considerable depth, taking account of the scientific knowledge gained in the earlier grades. Those sections involving review of previous work will be covered fairly rapidly making use of experiments and reading assignments, but it is expected that they will be extended to include a reinterpretation in the light of modern theories. *Problems are to be considered an essential part of each section of the course.*

The course is based on the work of the Physical Science Study Committee in the United States. Because student participation in experiments is considered essential for the P.S.S.C. treatment of the content, much inexpensive apparatus has been designed to allow this approach. In addition, the P.S.S.C. has prepared a wealth of supplementary material in the form of films, manuals, and guides. Teachers are advised to investigate this material for assistance in presenting the course content.

A suggested time allotment for each part of each unit has been included in the outline. While this allotment should be considered flexible within each of the four units, the teacher is advised not to exceed the total time suggested for any unit.

UNIT 1: THE UNIVERSE

Unit 1 is a general introduction to the fundamental physical notions of time, space, and matter. It begins with a study of instruments and methods of measurement of time and space, and then extends to an investigation of matter in motion.

1. **Time and Measurement** (3 periods)

   (a) Time as a measure of the sequence of events

   The comparison of time-intervals of repeated events

   Methods of measuring short and long time-intervals

   (b) An experiment to measure short time-intervals using a stroboscope

   (c) The expression of large and small numbers in scientific notation

   The concept of the order of magnitude of physical quantities

2. **Space and its Measures** (4 periods)

   (a) The concept of distance as the measure of space intervals

   The need of a standard unit of length

   The use of the metric units and the prefixes

   (b) A brief discussion of the methods for measuring large and small distances

   A monolayer experiment for determining the dimensions of molecules

   (c) The limitations of measurements and the use of significant figures to express the accuracy of measurements

   Significant figures in calculations involving measured quantities

3. **Matter and Mass** (1 period)

(a) The concept of mass as a measure of matter

The measurement of gravitational mass in metric units

The range of masses in the universe

(b) Development from general observations and from precise measurements of the concept that matter and mass are conserved

4. **Functions** (3 periods)

(a) The use of equations and graphs for expressing relations among physical quantities in

(i) direct variation

(ii) inverse variation

(iii) the power laws, especially the inverse square

(b) The use of interpolation and extrapolation, and their limitations

5. **Motion Along a Path** (9 periods)

(a) Review of the concept of speed to establish that distance travelled is the product of speed and time

Extension to speed-time graphs and the area under a speed-time graph as a measure of the distance travelled

(b) The description of motion using distance-time graphs

(i) the slope of the line between two points on a distance-time graph as a measure of the average speed of a moving object

(ii) the slope of the tangent at a point on a distance-time graph as a measure of the instantaneous speed of an object having a varying speed

(c) Review of the concept of acceleration

Extension to the determination of average and instantaneous accelerations as slopes on speed-time graphs

(d) Derivation from a speed-time graph of algebraic relations between distance, acceleration, and speed

(e) Experimental determination of the speed and acceleration of a moving object

6. **Vectors** (6 periods)

(a) The use of a vector quantity to describe directed displacements

(b) The addition and subtraction of vectors, and applications of these operations to velocity vectors

(c) The algebraic treatment of vector problems using the components of vectors and the products of vectors and scalars

(d) Acceleration as a measure of the rate of change of velocity

(e) Descriptions of motions in which the acceleration changes in magnitude or direction

UNIT II: OPTICS AND WAVES

Unit II reviews and extends the previous study of light to develop an explanation of the behaviour of light in terms of wave motion.

1. **How Light Behaves** (2 periods)

(a) Sources, Transmission, and Detection of Light

Luminous and non-luminous objects

Behaviour of light striking transparent, coloured, and opaque materials

Light-sensitive devices: the eye, photographic film, photocells

Rectilinear propagation of light

Lack of necessity for a medium

(b) Some Properties of Light

Diffraction: recognition of its existence under certain circumstances

Invisible light: ultraviolet and infrared

The speed of light in air and in a vacuum

2. **Reflection and Images** (2 periods)

(a) Light Beams, Pencils, and Rays

Shadows and the effects produced by large and small sources of light

Binocular vision

(b) Reflection

Terminology

The laws of reflection verified by experiment

Images: (i) geometric location by ray diagrams

(ii) diagrams to show how the eye views the image

3. **Refraction** (4 periods)

(a) The Laws of Refraction

The first law of refraction

Refraction of light by various transparent media

Experiment to discover Snell's Law

Applicability of Snell's Law to light travelling in either direction

The meaning of the absolute index of refraction

(b) The Relative Index of Refraction and Total Reflection

Passage of light from water to glass

Meaning of the relative index of refraction

Demonstration to illustrate total internal reflection and critical angle

(c) Dispersion

Demonstration and explanation of the dispersion of white light by a prism

4. **The Particle Model of Light** (3 periods)

(a) Successes of the Particle Theory

The concept of a scientific theory or model

Assumptions regarding size and velocity of light "particles"

Examination of the particle theory as applied to (i) reflection, (ii) refraction

Consistency of the particle theory with (i) the inverse square law, (ii) light pressure, (iii) absorption and heating

(b) Failures of the Particle Theory

Failure of the theory to account adequately for (i) partial reflection and refraction, (ii) the speed of light in water, glass, etc., (iii) diffraction phenomena

The value of the particle model and the need for a modified or new theory

5. **Waves** (2 periods)

(a) Introduction to Waves

A review of the concept of a wave as a disturbance that travels without transfer of material

A study of the propagation of waves in a coil spring or rope as an example of transverse waves

(b) Superposition of Waves

The crossing of waves originating from opposite ends of a spring

(c) Reflection and Transmission

The reflection of a wave from a fixed and free end

The partial reflection and transmission of a wave when it reaches a boundary between two different springs

(these properties of waves should be adequately demonstrated)

(d) A Wave Model for Light

A preliminary consideration of the wave as a suitable model for light

6. **Waves and Light** (5 periods)

(a) Water Waves

The properties of water waves and the production and propagation of straight and circular waves in the ripple tank

The reflection of straight waves at a barrier and the resemblance of the action to that of reflection for light

(b) Periodic Waves

A discussion of periodic waves: period [T], frequency (f), velocity [v], wave length (λ), and the relation $v = \frac{\lambda}{T}$

An experiment on the production and measurement of straight periodic waves in a ripple tank

(c) Refraction and Dispersion

The dependence of the speed and the wave length of periodic water waves upon the depth of the water

Demonstration of Snell's law for water waves as further support for the wave model of light

An experiment on refraction of straight waves with a ripple tank

(d) Diffraction

An introduction to the phenomenon of diffraction by discussion and demonstration of water waves passing through openings

The dependence of the prominence of diffraction effects upon the relation between the size of the opening and the length of the wave

Further support for the wave model of light

7. **Interference** (3 periods)

(a) Interference of Periodic Waves

Brief consideration of interference of pulses and periodic waves in ropes and springs

Thorough discussion of the interference pattern produced by two point sources generating periodic circular waves

Development of the relationship connecting wave length, source separation, and the direction of the region of zero disturbance (nodal lines)

An experiment using the ripple tank to enable the student to observe the interference pattern for two periodic point sources and to make measurements to check the interference relationship

(b) Effect of Phase

A brief consideration of the effect of the relative phases of sources on interference patterns

Demonstration of this effect using the ripple tank

8. **Light Waves** (5 periods)

(a) Interference of Light Waves

A discussion of the conditions that must be fulfilled in order to observe interference of light

Young's double-slit interference experiment

Calculation of the wave lengths for different colours in the double-slit interference experiment

The relation between colour and wave length of light

(b) Diffraction

A discussion of the diffraction pattern of a single slit and its explanation

A demonstration of the diffraction patterns of single and double slits

(c) Thin Films

Explanation of interference patterns produced by light incident on thin films

Colour effects in the interference patterns when white light is incident

(d) Summary

A brief summary of the wave aspects of light and reference to other problems relating to waves and light which will be considered later

Unit III: MECHANICS

Unit III extends the study of Newtonian physics to develop a further understanding of the laws of motion, of gravitation, and of their application to problems of potential and kinetic energy.

1. **Newton's Laws of Motion** (6 periods)
   (a) Distinction between kinematics and dynamics
   Discussion of motion without force
   Reference to Galileo's experiments and Galileo's law of inertia (Newton's first law)
   (b) Discussion of change in velocity
   Experiments with a truck or trolley pulled by different forces, F, 2F, 3F, etc.
   Inertial mass and change in velocity
   Experiments with loaded trucks pulled by a constant force
   Newton's Second Law
   Comparison of inertial and gravitational mass
   (c) Vector addition of forces
   Resultant or unbalanced force

2. **Motion in the Earth's Gravitational Field** (9 periods)
   (a) Weight and mass
   The gravitational field of the earth
   Acceleration of a freely falling object near the surface of the earth
   Independence of the components of forces and of motions
   Projectiles and their paths
   (b) Circular motion
   Experimental study of angular velocity, angular acceleration, and centripetal force
   Earth satellites
   (c) Frames of reference
   Necessity for unaccelerated frame for Newton's second law
   Foucault's pendulum

3. **Universal Gravitation and the Solar System** (6 periods)
   (a) Introduction to the history of planetary systems
   Reference to the work of Copernicus and Brahe

Kepler's Laws
Kinematics of the planetary system

(b) Frame of reference for dynamical consideration

(c) Newton's analysis of the dynamical problems inherent in Kepler's Laws

(d) Universal gravitation

4. **Momentum and the Conservation of Momentum** (8 periods)

(a) Impulse and momentum
The kinematic nature of momentum
Experimental study of momenta of interacting bodies and the conservation of momentum
Application of conservation of momentum to rockets and satellites

(b) Newton's third law
Forces of interaction

5. **Work and Kinetic Energy** (8 periods)

(a) Work as a measure of energy transfer
Definition of work

(b) Kinetic energy and its relation to work
Transfer of kinetic energy by collision
Conservation of kinetic energy with experimental illustration

(c) Application of conservation of momentum and conservation of energy to elastic collision problems

(d) Loss of kinetic energy in frictional interactions

6. **Potential Energy** (7 periods)

(a) Stored energy in a stretched or compressed spring
Conservation of mechanical energy in an elastic collision

(b) Grativational potential energy near the surface of the earth
Gravitational potential in general

(c) Escape energy and escape velocity of satellites

(d) Experimental study of the transfer of gravitational potential energy to potential energy of a stretched spring

Conservation of mechanical energy

7. **Heat, Molecular Motion, and Conservation of Energy** (4 periods)

(a) Temperature as proportional to average kinetic energy of molecular motion

Additional or removal of thermal energy to raise or lower temperature or to cause change of state

(b) Mechanical energy of bulk motion and internal energy

(c) The general principle of conservation of energy

Unit IV: ELECTRICITY AND ATOMIC STRUCTURE

Unit IV develops a quantitative approach to electricity to extend the qualitative investigation carried out in Grade 11. The student is introduced to modern atomic ideas and the wave nature of matter.

1. **Introduction to Electricity** (3 periods)

(a) Attraction and repulsion

Differences between insulators and conductors

Charging by contact

Charging by induction

(b) Identification and measurement of electric charges

(c) Batteries as a permanent source of charge

(d) Movement of charged particles in gases, liquids, and metals

Thermionic emission

2. **Coulomb's Law and Elementary Electric Charge** (7 periods)

   (a) The inverse square law as applied to electric charges

   (b) Discussion of Coulomb's Law

   (c) Vector considerations of electric field forces
   Measurement of small electric forces
   The electrical balance
   The magnitude of the elementary charge

   (d) The constant in Coulomb's Law
   The force between elementary charges

   (e) The electric charge on electrons and on other particles

3. **Energy and Motion of Charges in Electric Fields** (8 periods)

   (a) Motion of electrons and protons in a uniform electric force field

   (b) Discussion of methods by which the mass of the electron and proton can be determined

   (c) The electric current
   Electrolyte measurement of electric current to show the relationship of ionic charge to electron charge

   (d) Battery as an energy source providing a fixed amount of energy per elementary charge

   (e) Meaning of electric field and electrical potential difference
   Definition of electrical potential difference as energy per elementary charge

4. **The Electromagnetic Spectrum** (1 period)

   A qualitative discussion of evidence for electromagnetic radiation

   The electromagnetic spectrum

5. **Exploring the Atom** (6 periods)

   (a) Discussion of alpha particle scattering experiments which show that most of the mass of an atom is concentrated in a nucleus less than 4×10^{-14} metres in radius and that the charge on the nucleus is proportional to the atomic number.

   (b) Contradictions present in the Rutherford atomic model

      (i) atoms do not continuously radiate light as their electrons spiral in toward the nucleus

      (ii) atoms, when excited, radiate only certain frequencies, not a continuous spectrum

6. **Photons and Matter Waves** (10 periods)

   (a) Random emission of electrons from oil drops when illuminated by X-rays or ultraviolet radiation as demonstrated in the Millikan experiment
   Evidence of particle nature of light
   Photons

   (b) Interference effects in extremely weak light (less than one photon at a time)
   Photons exhibiting wave properties

   (c) The photoelectric effect
   Einstein's interpretation of photoelectric effect
   Einstein's equation: Maximum electron energy $= h\nu - B$

   (d) The Compton effect
   Momentum of a photon: $p = mv$

   (e) Electron diffraction
   Matter waves
   The de Broglie wave length: $\lambda = \frac{h}{p}$

7. **The Structure of Atoms** (10 periods)

   (a) Discussion of discrete energy levels of atoms illustrated by a description of the Franck-Hertz experiment
   Excitation energy, energy levels, ionization energy

(b) Atomic emission spectra and energy levels

$$h\nu = E_{initial} - E_{final}$$

(c) Atomic absorption spectra

$$E_{final} = E_{initial} + h\nu$$

(d) The spectrum of atomic hydrogen
The Balmer and Lyman series
Energy levels of atomic hydrogen

$$E_n = \frac{-13.6}{n^2} \text{ electron volts}$$

(e) An account of energy levels of atoms in terms of standing wave patterns of de Broglie waves (matter waves)
The basis of wave mechanics